The Dark Energy Camera (DECam) Project

Conceptual Design Report

Version 0.4
May 11, 2006

The Dark Energy Survey Collaboration [1]

Changes in this draft compared with previous distribution:

Uses alternate outline discussed on Apr 28
Revises content in most sections
Implements edits to 2.2 from Josh
Addresses comments from Ed
Addresses comments from Mont

[1] Fermi National Accelerator Laboratory, University of Illinois at Urbana-Champaign, University of Michigan, …

1. Introduction: The Science Context of the Dark Energy Survey

A critical research problem in cosmology is the drive to understand the observations of an accelerating expansion of the universe. In 1998 two independent teams studying very distant supernovae observed that Type 1a supernovae appeared dimmer than expected. This dimness could be explained by either evolution in the intrinsic luminosity of the supernovae or an acceleration of the universal expansion. The gravitational attraction of galaxies and their dark matter halos decelerates the expansion and this acceleration requires something new and strange: dark energy. Since then independent lines of evidence for dark energy have been found.

The high precision measurements of the temperature fluctuations of the cosmic microwave background (CMB) made with the NASA Wilkinson Microwave Anisotropy Probe (WMAP) mission showed that the geometry of the universe is flat to within the errors of their measurements. A flat universe requires that the total energy density must be equal to a critical value. The Sloan Digital Sky Survey and WMAP have determined that the total matter density, the sum of the normal and dark matter densities, is equal to 30% of this critical value. The remaining 70% of the energy density is attributed to the unseen dark energy—in agreement with the supernova studies.

The dark energy could be a simple vacuum energy density (the “cosmological constant”) or a flaw in Einstein’s general relativity or evidence that our world lies embedded in a much higher dimensionality universe. Any of these possibilities represent a major shift in our current understanding of the nature of matter, energy, space and time. However, to sort out the possibilities and pin down the nature of the dark energy, we will need more precise measurements of the dark energy equation of state parameter, w. We also need to determine whether the amount of dark energy in the universe has changed with time – that is, whether the equation of state should be described with both a constant and a time-dependent term. In order to make these measurements, new methods and new instruments are needed.

2. Justification for the DECam Project

2.1 Mission Need for a Ground-Based Dark Energy Experiment

The Mission Need Statement for a Ground-Based Dark Energy Experiment, approved in November 2005, discussed the science case for better precision in the measurement of dark energy. It also noted the support from a recent report from the National Research Council (*Connecting Quarks with the Cosmos,* April 2002) and from the National Science and Technology Council's strategic plan to respond to that report (*ThePhysics of the Universe,* 2004) for a dark energy program using multiple techniques from space and from the ground. It stated:

" A project to build a ground-based detector or facility capable of studying dark energy will support the Department of Energy's Strategic Plan dated September 30, 2003: *To protect our national and economic security by providing world-class scientific research capacity and advancing scientific knowledge.* Specifically, it will support the two Science goals: *1) Advance the fields of high-energy and nuclear physics, including the understanding of dark energy…* and *7) Provide the Nation's science community access to world-class research facilities…*"

The Mission Need statement then identified three options that could provide complementary ground-based measurements of dark energy as the next steps in a robust dark energy program. We believe Option 1 offers the fastest approach to make the next step in increasing our understanding of dark energy. Option 1 was described as:

"Construct a large-scale charged-coupled device (CCD) camera for galaxy cluster counting and other dark energy measurements. The camera could be installed on the Blanco 4m Telescope in Chile. The combination of this telescope and camera with the necessary sensitivity will make it more than 10 times more powerful than any existing facility. In combination with galaxy cluster mass measurements from other telescopes, the data would provide the first high precision (5 – 10% statistical errors) dark energy constraints."

The National Optical Astronomy Observatory (NOAO) issued an announcement of opportunity (AO) in December 2003 for an open competition to partner with NOAO in building an advanced instrument for the Blanco telescope in exchange for awarding the instrument collaboration up to 30% of the observing time over a five-year period for a compelling science project. In response to this AO, the Dark Energy Survey (DES) Collaboration was formed and submitted a proposal to NOAO in July 2004 to build DECam, a new wide-field imager for the Blanco, with the goal of carrying out a survey to address the nature of the dark energy using the four primary techniques described below in Sec. 2.2. The Blanco Instrumentation Review Panel convened by NOAO to review the DES proposal in August 2004 concluded that the scientific goals are exciting and timely. Subsequently, the NOAO Director asked the CTIO Director and the DES Project Director to draft an MOU among the Parties that would define the terms of the partnership. Since that time, the Dark Energy Survey collaboration has further developed the ideas in the proposal and has been strengthened by the addition of strong partners from two international consortia [1,2] and from US universities. The collaboration has conducted R&D to determine more firmly the feasibility of the project, and is now ready to request the next level of approval for the project to construct an instrument which would meet the need expressed in Option 1.

[1] Spanish Consortium: IFAE, …
[2] British Consortium:

2.2 Does the DECam Project Satisfy Option 1 in the Mission Need Statement?

The Dark Energy Camera (DECam) Project is a project to build a 3 deg^2 imaging camera composed of 62 2K x 4K imaging CCDs, plus associated guide and focus CCDs. The Dark Energy Survey (DES) will use this camera to conduct a five-year survey of ~3 x 10^8 galaxies over a 5000 sq deg area, with photometric redshift determinations out to redshifts of ~1.3, encompassing the entire survey area covered by the South Pole Telescope (SPT). The data obtained with this survey will enable substantial improvement in the determination of the dark energy equation of state, w. Parametrizing the redshift evolution of this quantity as $w(a)=w_0 + w_a \times (1 - a)$, the Dark Energy Task Force has defined a figure of merit that is inversely proportional to the area of the error ellipse in this two-dimensional parameter space. Their forecasts and our own indicate that DES should achieve a statistical precision in the figure of merit which is at least 3 times better than the current state of knowledge, by the use of 4 independent techniques.

The four techniques which DES proposes to use for probing dark energy are described briefly, below. More detail on these techniques is available in the DES white papers, submitted to the Dark Energy Task Force, which are available at [link].

***Galaxy clusters*:** Measuring the number of galaxy clusters as a function of redshift provides a sensitive probe of the dark energy through both the cosmic expansion history and the growth rate of large scale structure. DES was designed with the goal of being able to perform this measurement in the most effective way, by making use of the overlap with the South Pole Telescope (SPT) to combine DES photometric redshift and statistical weak lensing mass measurements with clusters identified by the Sunyaev-Zel'dovich effect (SZE) from SPT. DES will also be able to provide a crucial cross-check of the completeness of the SPT cluster selection function by optically identifying clusters below the SPT mass threshold. Existing cameras would require decades to cover the SPT survey area to the requisite depth for this measurement. Given the independent selection and measurement of clusters in the DES optical survey and the SZE survey, we will be able to achieve improved control of systematic errors for the cluster dark energy measurement.

Weak lensing tomography: Weak lensing shear is a measure of the change of the apparent shape of galaxies produced by the gravitational light-bending effects of mass along the line of sight to the observer. DES will measure the weak lensing shear of galaxies as a function of photometric redshift. As with clusters, the redshift evolution of the statistical pattern of lensing distortions is sensitive to the dark energy through both geometry (that is, distances that depend on the cosmic expansion history) and the growth rate of structure. In the course of surveying 5000 deg^2 to the depth needed to count clusters, DES will measure shapes and photometric redshifts for ~300 million galaxies and, with improved design and control of the optical image quality, enable accurate measurement of lensing by large-scale structure.

***Baryon Acoustic Oscillations*:** DES will measure the angular clustering of galaxies in photometric redshift shells out to redshifts beyond 1. The angular power spectrum of galaxy clustering shows characteristic features, a broad peak as well as baryon wiggles arising from the same acoustic oscillations that give rise to the Doppler peaks in the CMB temperature anisotropy power spectrum. These features in the pattern of galaxy clustering were recently detected in the SDSS at low redshift, z~0.3. In combination with CMB observations, they serve as standard rulers for distance measurements, providing a geometric probe of the dark energy.

Supernova luminosity distances: In addition to the wide-area survey, the DES will use 10% of its allocated time to discover and measure well-sampled multi-band light curves for ~1900 Type Ia supernovae in the redshift range $0.3<z<0.75$ through repeat imaging of a 40 deg^2 region. As standardizable candles, these supernovae will provide (geometric) distance estimates that constrain the properties of the dark energy.

DES is able to acquire the data for the first 3 listed techniques with the same survey strategy on the same instrument. The combined constraints on w_0 and w_a from the four techniques are shown in Fig. 1 [diagram from Josh's P5 talk]. There are two points to note about this combination of constraints. Of the four techniques, the BAO and SN measurements are sensitive only to the effect of cosmological parameters on geometry, while the cluster and weak lensing measurements are sensitive to their effects on both geometry and the growth of large scale structure. Having comparable precision from the full complement of techniques, to the levels DES can achieve, should yield information that will help distinguish between different types of explanation for dark energy. The other notable point is that the contours shown in Fig 1 are marginalized over other parameters (omega-b, etc.) and the four techniques have different sensitivities to those parameters. It is that latter point which gives the combination of the four its great power in constraining the dark energy equation of state.

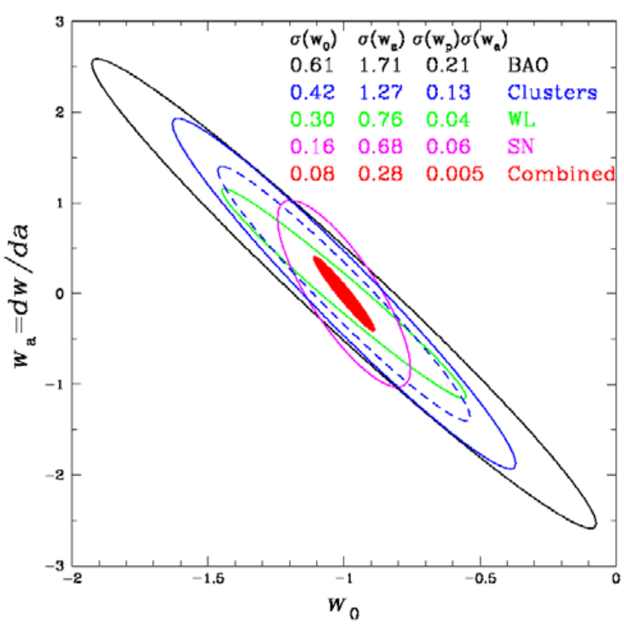

Fig. 1 DES constraints on the DE 2-param equation of state

2.3 Comparison of DECam to Alternatives for This Mission Need

We believe the DECam Project is the only proposal to date which meets the objectives stated for Option 1 of the Mission Need statement: to provide the first opportunity to get a high precision measurement of the dark energy parameters. Executing the DECam project has additional value in terms of providing a medium-term trial with a real, significant dataset for the simulation and analysis techniques required in a large-scale dataset to constrain dark energy. This experience will be scientifically useful for projects which will satisfy Option 3 in the ground-based CD0 statement of need, and also for a space-based project that tackles dark energy.

The DECam program is complementary to, rather than competitive with, any project designed to meet the mission need specified in Option 2, which is specified as:

"Build a spectrograph to be used on an existing wide field of view telescope for baryonic oscillation measurements. Such a detector would be 10 times more powerful than any yet built and would obtain a massive galaxy redshift survey. The measurements of the variation in baryon particle densities would be used to determine the nature of dark energy at higher redshift, $2 < z < 4$, than is possible with other experiments."

The program specified as Option 3 is longer term and much larger in scale – of cost and of difficulty – than the DECam project. This option is described as:

"Build a next-generation wide-field telescope along with the world's largest optical imaging camera and associated data acquisition system. This concept would allow measurements of galaxy shape distortions caused by weak gravitational lensing to determine the growth of galaxy clusters over time. It is expected that other agencies or institutions would provide funding for the telescope. Such a facility could obtain sequential images of the entire visible sky every few nights and the data collection area would be two orders of magnitude larger than any existing facility. Data will be of use to the larger astrophysics and astronomy community for many different science topics. The data would provide high precision dark energy constraints at the approximately 2 – 3% level."

The Mission Need statement also lists an Option 4, which is to build no new facilities targeting dark energy measurements. We certainly feel that this choice is incompatible with the strategic priorities of DOE as referenced in the statement.

2.4 The Cost Range of DECam Project

In this section, we describe the costs to the DOE of the DECam project, which will be approximately 60% of the cost of the Dark Energy Survey. The other 40% of the cost is expected to be covered by funds from our international partners, the NSF, and funds from collaborating universities in the US.

The construction funding for the DECam project is anticipated to arrive in FY08, and have a three-year profile through FY10. The funding will cover the production of CCDs in final packaging for the focal plane array, the assembly and testing of that array at Fermilab, the assembly and testing of the readout electronics for the CCDs, the construction of the camera vessel and its associated cooling and controls infrastructure, the construction of a corrector barrel to hold the lenses that form the optical corrector system, and the construction of an infrared all-sky camera to monitor sky conditions at the Cerro Tololo site. The proposed funding profile, including overheads and using then-year dollars, is shown in Table 1.

Funding for the lenses in the optics system is anticipated to come from PPARC proposal xxxxx. The readout electronics will include some boards designed and produced with external funding from [Spanish Agency here], but the full readout system will be tested at Fermilab. The data management part of the project, including long term data storage of the survey results, is anticipated to receive funding from NSF proposal xxxxx.

[Table 1: construction funds only, M&S, labor, total MIE ??]

At this point, we anticipate a range of xxM$ to yyM$ for the project cost.

2.5 The Schedule Range of the DECam Project

[Paragraphs copied from Flaugher SPIE paper]
A schedule for the DES project was prepared and reviewed in June 2004 as part of both the Fermilab and NOAO project review process. The procurement of the CCDs and the optical elements were identified as the critical path items for the project. Since those reviews, we have focused our resources on addressing these topics. We are on a schedule for delivery of DECam to CTIO in 2009, assuming that funding from the several national agencies can be solidified over the next year.

The optics are one of the critical path elements primarily because of the lengthy (2-2.5yr) estimated procurement. We held a Project Director's Review of the Optical design in February 2006 to obtain early feedback from external reviewers. Their response to the DES design was positive and they urged us to move forward with the rest of the mechanical design. We plan to have a review of the full DES project (which encompasses more than the DECam project being described in this document) in July 2006 with the goal of being ready to place the order for the glass blanks in August, or as soon as the funding is secured.

The CCDs are also on the critical path due to the estimated delivery rate (5 wafers per month plus a 3 month startup) combined with the uncertainty in the CCD yield. The silicon processing for these devices is under development, and it is difficult to estimate the final yield results until all the issues in the processing chain have been understood. Assuming the yield is 25%, production of 70 good devices would require ~ 18 months of processing, packaging and testing. By December 2006, we should have more information on the CCD yield. This will feed directly into the project cost and schedule. The high level schedule elements of the DECam project are shown in Table 2.

DES Timeline:
R&D FY06,07 CCDs: establish packaging and testing procedures, develop firm estimate of yield
Develop full prototype of prime focus CCD electronics and the SISPI
Finalize optical design and place contracts for the lenses with non-DOE funds
FY08 DOE Construction Start:
Production processing of CCD wafers at LBNL
Production CCD packaging and testing
Production CCD readout and image assembly system
Camera vessel construction
FY09-FY10 Complete CCD production, packaging and testing
Assemble and test full focal plane
Assemble and test optical corrector
Ship to Chile June 2009
First light Oct. 09
First DES observations Dec. 09
[make this into a table format]
[End insert from SPIE]

3. Scientific and Technical Requirements

3.1 Site Selection

As the DECam Project is a specific answer to an announcement of opportunity for an instrument to be placed on the Blanco 4m telescope, which is an existing facility of the Cerro Tololo Internamerican Observatory in Chile, site selection is not an issue for the DECam project. No other existing 4m telescope with comparable seeing, and offering the considerable advantage of overlap in available survey volume with the South Pole Telescope's survey, is available for this work.

3.2 Scientific Requirements

3.3 Technical Requirements

The major components of DECam are a 519 megapixel optical CCD camera, a 2.2 deg. field of view optical corrector, a 4-band filter system with SDSS *g, r, i,* and *z* filters, guide and focus sensors mounted on the focal plane, a low-noise CCD readout, a cryogenic cooling system to maintain the focal plane at 180 K, as well as a data acquisition and instrument control system to connect to the Blanco observatory infrastructure. The camera focal plane will consist of sixty-two 2k x 4k CCDs (0.27 arc-seconds/pixel) arranged in a hexagon covering an imaging area of 3 sq. degrees. The smaller format guide and focus CCDs will be located at the edges of the focal plane.

The Dark Energy Survey (DES) Collaboration will have available 30% of the observing time on the Blanco telescope. Around 500 nights of observations will be required to reach the survey's goals, so the survey will require 5 years for completion. Within that time, it can reach photometric limits of magnitude 24 or better for faint galaxies, in all four of its filters. These limits and adopted median delivered seeing are derived from detailed survey simulations that incorporate weather and seeing data at CTIO over a 30-year baseline.

The survey strategy is designed to optimize the photometric calibration by tiling each region of the survey with at least four overlapping pointings in each band. This provides uniformity of coverage and control of systematic photometric errors via relative photometry on scales up to the survey size. It will enable us to determine photometric redshifts (photo-z's) of galaxies to an accuracy of $\sigma(z)\sim0.07$ out to $z>1$, with some dependence on redshift and galaxy type, cluster photometric redshifts to $\sigma(z)\sim0.02$ or better out to $z\sim1.3$, and shapes for approximately 200 million galaxies; these measurements will be sufficient to meet the survey science requirements. 4000 deg^2 of the survey region will overlap the South Pole Telescope Sunyaev-Zel'dovich survey region; the remainder will provide coverage of spectroscopic redshift training sets, including the SDSS southern equatorial stripe, and more complete coverage near the South Galactic pole.

3.4 Performance Parameters of the Blanco Telescope and the DECam Instrument

In order to meet the science objectives outlined in Section 3.2, DECam must obtain images of 5000 square degrees of the Southern Galactic Cap with four filters. Meeting these objectives requires a large CCD camera, optical corrector, integrated filter and shutter mechanism, the 4 meter Blanco telescope, and the electronics and software to integrate DECam with the Blanco (SISPI). As noted elsewhere the Blanco telescope at the Cerro Tololo Interamerican Observatory will be provided by NOAO. The primary detector performance requirements for DECam and the Blanco are:

Table 1: Expected performance of DECam, Blanco, and CTIO site

Blanco Effective Aperture/ f number @ prime focus	4 m/ 2.7
Blanco Primary Mirror - 80% encircled energy	0.25 arcsec
Optical Corrector Field of View	2.2 deg.
Wavelength Sensitivity	400-1100 nm
Filters	SDSS g, r, i, z
Effective Area of CCD Focal Plane	3.0 sq. deg.
Image CCD pixel format/ total # pixels	2k X 4k/ 519 Mpix
Guide, Focus & Wavefront Sensor CCD pixel format	2k X 2k
Pixel Size	0.27 arcsec/ 15 μm
Readout Speed/Noise goal	250 kpix/sec/ 5 e
DECam Corrector 80% encircled energy (center/edge)	g (0.32/0.59 arcsec) r (0.11/0.37 arcsec) i (0.17/0.41 arcsec) z (0.31/0.47 arcsec)
Survey Area	5,000 sq. deg.
Survey Time/Duration	525/5 (nights/years)
Median Site Seeing Sept. – Feb.	0.65 arcsec
Median Delivered Seeing with Mosaic II on the Blanco	0.9-1.0 arcsec (V band)
Limiting Magnitude: 10σ in 1.5" aperture assuming 0.9" seeing, AB system	g=24.6, r=24.1, i=24.3, z=23.9
Limiting Magnitude: 5σ for point sources assuming 0.9" seeing , AB system	g=26.1,r=25.6, i=25.8, z=25.4

[Discuss the Blanco telescope improvements here.]

4. Description of the DECam Project

4.1 DECam Conceptual Design

The philosophy of the DECam project is to build a powerful survey instrument, using technologies whose lead time to production is not too long, and mount the instrument on an optimally configured Blanco, thereby exploiting an excellent, existing telescope. The major components of DECam are listed in Section 3.3 and Figure 1 shows a cross section of DECam with the key elements identified. A discussion of the Blanco performance and upgrades are given in Section 3.4.

To efficiently obtain *z*-band images for high-redshift (z~1) galaxies, we have selected the fully depleted, high-resistivity, 250 micron thick silicon devices that were designed and developed at the Lawrence Berkeley National Laboratory (LBNL) (Holland et al. 2003). The thickness of the LBNL design has two important implications for DES: fringing is eliminated, and the QE of these devices is > 50% in the *z* band, a factor of ~10 higher than traditional thinned astronomical devices. Several of the LBNL 2k x 4k CCDs of this design have been successfully used on telescopes, including the Mayall 4m at Kitt Peak and the Shane 3m at Lick. The DES CCDs will be packaged and tested at Fermilab, capitalizing on the experience and infrastructure associated with construction of silicon strip detectors for the Fermilab Tevatron program. The CCD packaging plan for the four side buttable 2k x 4k devices builds on techniques developed by LBNL and Lick Observatory.

The optical corrector reference design consists of five fused silica lenses that produce an unvignetted 2.2^{o} diameter image area, which is calculated to contribute < 0.4" FWHM to the point-spread function. Element 1, the largest, is 1.1m in diameter and the surface of another is aspheric. The spacing between elements 3 and 4 will allow the 600 mm diameter filters to be individually flipped in and out of the optical path. DECam will be installed in a new prime focus cage.

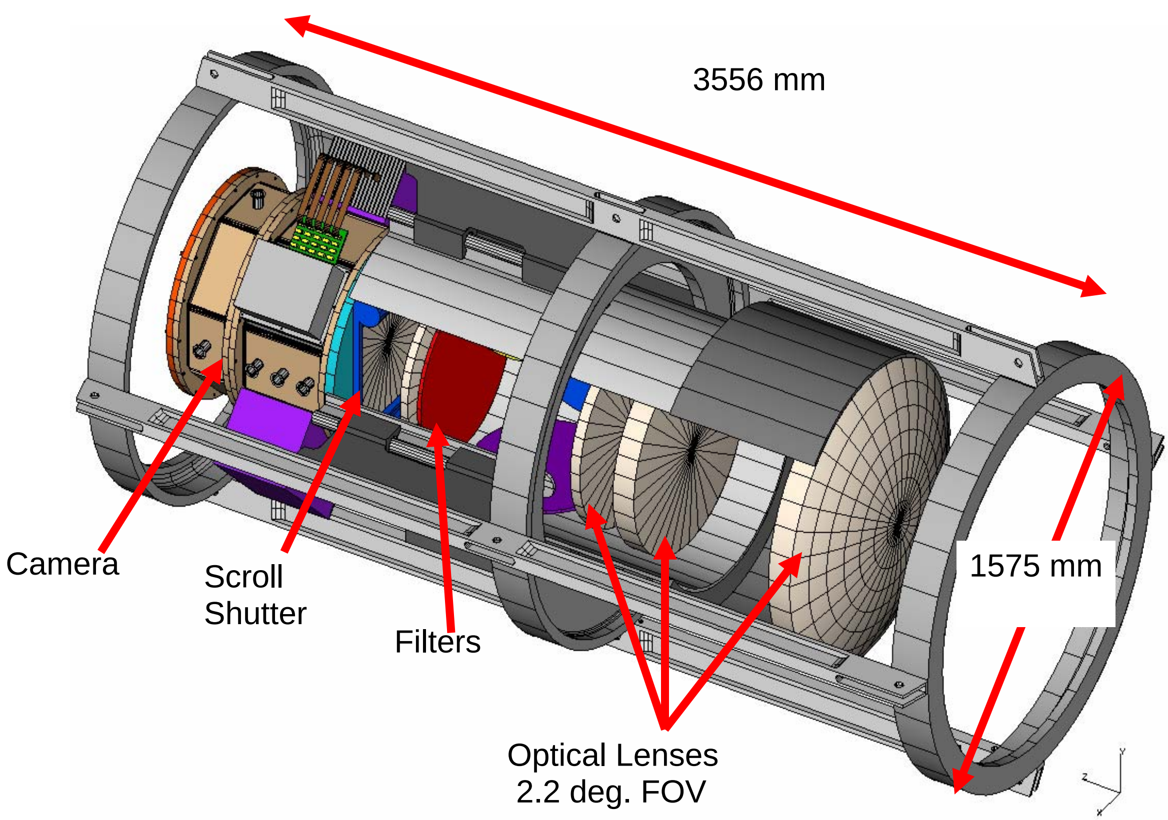

Figure 2: DECam Reference Design

To benefit from the on-going development at NOAO, we have adopted the Monsoon CCD readout system as a starting point. UIUC and Fermilab each have a Monsoon system and are preparing to read out LBNL CCDs in the near future. As we gain experience with Monsoon in the testing setups, we will build on the design and make the modifications necessary to meet the prime focus cage space and heat restrictions.

The risks associated with the optical design result from the size of the elements. We are investigating alternative designs with smaller first elements (~0.9m) and better image quality, with the goal of cost and schedule reduction. We have joined a group organized by George Jacoby to collaborate on the development of large filters for imaging cameras (WIYN, LSST, and PanSTARRS). We are also following the development of large colored glass filters at Schott.

4.2 Work Breakdown Structure for the Project

Table 3 shows the DECam WBS dictionary at Level 2. Further details of the WBS are in Appendix B. The project WBS and management structure parallels the project budget structure.

WBS	Task	Duration	Start	Finish
1.1	**Management**	**250.4 wks**	**4/30/04**	**5/12/09**
1.1.1	Reviews/approvals/proposals	225.2 wks	4/30/04	10/31/08
1.1.2	R&D Phase Management Support	147.2 wks	11/29/04	10/15/07
1.1.3	Project Management Support	108.4 wks	10/16/07	10/30/09
1.2	**Dark Energy Instrument**	**267.6 wks**	**7/7/04**	**11/20/09**
1.2.1	CCDs	206 wks	11/29/04	2/2/09
1.2.2	CCD Packaging	208.4 wks	11/29/04	2/18/09
1.2.3	Front End Electronics	198.6 wks	7/7/04	3/2/09
1.2.4	CCD testing and characterization	209 wks	11/29/04	2/23/09
1.2.5	Computing for CCD and Camera testing	137 wks	3/16/05	1/28/09
1.2.6	Camera Vessel, Focal plane	260.4 wks	7/15/04	10/9/09
1.2.7	Cooling and slow controls	254.4 wks	7/15/04	8/26/09
1.2.8	Optical design and components	223.8 wks	11/29/04	6/8/09
1.2.9	Corrector Barrel	168.2 wks	7/8/05	12/8/08
1.2.10	Primary Cage mechanics	235.4 wks	7/15/04	4/13/09
1.2.11	Auxiliary Components	214.2 wks	10/1/04	2/2/09
1.2.12	Instrument completion	47 wks	12/9/08	11/20/09

4.3 Project Deliverables

The final deliverables of the DECam project are:

Assembled and tested focal plane of 62 image + 10 alignment/focus CCDs
Completed camera vessel
Assembled and tested readout electronics system
Assembled and tested corrector barrel

[here we hit the inconsistency of the funding profile with the statement that the project ends with shipment to Chile in Oct 09 – how to handle?????]

4.4 Value Engineering for the DECam Project

Value Management, also known as Value Engineering, is defined as an organized effort directed at analyzing the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life-cycle cost consistent with required performance, quality, reliability and safety. The DECam project has applied the principles of value engineering during the conceptual design process. We list here some examples of value engineering decisions taken in the DES design. A major cost savings is achieved by the use of an existing telescope with excellent natural seeing and potential for improvements with modest investments at CTIO, as described in Section x.x. The decision to use the Monsoon system for CCD readout has already resulted in a considerable advance to the project R&D schedule, and if chosen by the Front End Electronics panel now reviewing the choices, will also result in a very considerable savings in engineering development costs. [Example from optics – ask Brenna.] Using the CCD design and fabrication process developed by LBNL for the SNAP project also provides a considerable savings in development costs.

5. The Dark Energy Survey

5.1 Deliverables to the Dark Energy Survey outside the DECam Project

[Describe contributions from other consortia and collaborators, incl Data Management]

5.2 Public and Stakeholder Input

5.2.1 Stakeholders in the DECam Project

The DECam Project involves the construction of a CCD camera and its associated mechanical infrastructure. The activity of construction will be carried out at Fermilab and at collaborating institutions, in accordance with established guidelines at these institutions, as well as any applicable local, state, or federal regulations. We do not anticipate any significant impact on the local community from the DES construction activity, so there should be no stakeholder issues from the general public.

The primary stakeholders for the DECam project are the Dark Energy Survey collaboration, and the broader astronomical community who wish to observe using the DECam instrument, or to utilize the survey data. The understanding of the DES obligations to the astronomical community is detailed in the Memorandum of Understanding between DES and NOAO, and is excerpted in the following section.

[excerpted from NOAO MOU]

5.2.2 Community Use of DECam and Access to Data Obtained with DECam

DECam will be a facility instrument that will be available for use on the Blanco by other observers, who will be selected by NOAO through peer reviewed proposals or through the agreement between the AURA Observatory and the University of Chile. Whenever possible, the policies for the use of DECam on the Blanco Telescope will be consistent with NOAO policy for facility instruments. It is expected that up to 70% of the time could be awarded to observers through the aforementioned processes.

CTIO, in consultation with the CTIO user community, will develop a priority list of filters in addition to those provided by the Collaboration, to enable additional community science. Purchase of these filters, and fabrication of suitable filter cartridges, will be the responsibility of CTIO. The development of calibration and reduction procedures, if different from those developed by the Collaboration and NOAO DPP for the DES, will be the responsibility of CTIO and NOAO DPP.

The Collaboration shall deliver the raw DES data obtained with DECam and the calibrated single images produced from this data by the Collaboration to NOAO DPP 12 months after the individual observations have been taken. The Collaboration and NOAO DPP plan to place the raw data and the calibrated single images in the NOAO Science Archive in order to make them available to the astronomical community. NCSA and NOAO plan to distribute the raw data and the archive-ready data products through an agreement between NOAO and NCSA, using the same NCSA facilities that will be used to distribute these products to the Collaboration. The Parties agree that this arrangement is in accord with the current AURA/NOAO Data Rights Policy. The AURA/NOAO data rights policies shall also be applied to science data obtained with time awarded to other observers on the Blanco with DECam through peer reviewed proposals to NOAO.

The final, public DES archive, which will be finished after the 5-year survey is completed, is the final program deliverable of the Dark Energy Survey. Maintenance of the final, public DES archive, which will be part of the NOAO Science Archive, will be the responsibility of the NOAO DPP after it is delivered to NOAO.

[end excerpt from MOU]

6. Managing the Project Responsibly

6.1 Environment, Safety, and Health

The design, construction and testing of DECam at Fermilab will be performed in compliance with the standards in the Fermilab ES&H Manual (FESHM), and all applicable ES&H standards in the Laboratory's "Work Smart Standards" set. In addition, all related work, including work performed off-site, will be performed in compliance with applicable federal, state and local regulations. All work done at collaborating universities will be performed in accordance with existing university policies and applicable national, state, or local regulations.

The Fermilab ES&H Section provides ES&H support for all activities at Fermilab, including guidance on ES&H issues, environmental monitoring and safety assessments. The Particle Physics Division ES&H and Building Management Department provides additional support for specific aspects of the camera construction.
Do we need a specific DECam safety committee? Minerva had this but I am assuming this is overkill for DECam.

Fermilab follows the principle of Integrated Safety Management. Each person involved in DECam is responsible for following good ES&H practices in the course of his or her own work. However, in addition to these ordinary responsibilities, the DECam Project has an assigned ES&H Coordinator, who directs the preparation of hazard analyses, ES&H reviews, and associated documentation. [Probably not yet – follow up on this with Strait/Bock]

6.1.1 The National Environmental Policy Act (NEPA)

In compliance with NEPA, the DECam Project submitted an Environmental Evaluation Notification Form, on the basis of which a Categorical Exclusion was granted on December 2, 2005 – Wyatt, again we should check with Brenna for the exact date this was signed.

6.1.2 Safety Assessment Documents

A draft DECam Hazard Assessment Document has been prepared for this Project and will serve as the basis for the Preliminary Safety Assessment Document (PSAD) required for CD-2. A Safety Assessment Document (SAD) will be prepared prior to installation and/or sustained operations of the completed Camera. [Who prepares the Hazard Assessment Document?]

Although the installation of the DECam detector is not part of the DECam project, life safety issues pertaining to the installation and operation of the detector have been considered as part of the life cycle assessment. In cooperation with NOAO, Fermilab has performed an assessment of life safety issues for DECam operations at the Cerro Tololo Interamerican Observatory. The assessment focused on operations at CTIO. ES&H procedures for installing instruments and operating the Blanco Telescope have already been established by AURA, the contractor for NOAO. A Safety Assessment Document (SAD) will be prepared prior to the delivery of DECam to CTIO.

6.1.3 Integrated Safety Management Plan

The DECam Project will be executed in accordance with the principles of Integrated Safety Management (ISM) as specified in DOE P 450.4. While direct implementation of ISM is a line management responsibility, it is also addressed at the project level. The

Project will prepare an ISM Plan, which addresses the following ISM principles. Do we need a specific ISM plan? Who prepares it???

Defining the Scope of Work, Identifying Hazards

Subproject managers are responsible for planning work, identifying ES&H concerns and resources needed to support the work. The DECam Project staff meets regularly with line and safety managers to discuss planned work and establish priorities. Progress on priority items is tracked and submitted in the monthly report.

The project has prepared a Hazard Analysis Document. This document and additional hazard analyses initiated by line management will be in conformance with the FESHM, Chapter 2060.

Developing and Implementing ES&H Controls

Applicable ES&H Standards are integrated into all project planning documents. Work processes are documented and reviewed.

Where applicable, the project tasks with identified ES&H hazards will specify appropriately trained workers or else the schedule will allow for adequate training. Where possible, the project schedule will allow for dry runs of hazardous procedures.

Assessing Performance for Continuous Improvement

The project will undergo periodic ES&H reviews. These reviews may be conducted jointly by Fermilab and the DOE, and may be part of technical reviews of subprojects rather than standalone reviews. Reviews will generate recommendations that will be addressed by the project in a timely manner. More details on the various reviews DECam will undergo are given in Section 7.

6.1.3 Waste Minimization/Pollution Identification

Waste Minimization and Pollution Prevention (WM/P2) concepts will be embedded into all aspects of research and operations at Fermilab. A strong WM/P2 program is an integral part of the Laboratory's Environmental Management System. Fermilab's WM/P2 Program reflects Department of Energy, national and local WM/P2 goals and policies. It represents an ongoing effort to integrate WM/P2 with our research mission.

Fermilab's WM/P2 program is anchored by three tenets commonly associated with pollution prevention objectives. They are Reduce, Reuse and Recycle. DECam is doing all of these in the design process and will continue to during the life of the project and on through the operation of the experiment. Specifically, the materials DECam is recycling include any discarded electronic equipment from the prototyping or production phases, via Fermilab's lab-wide electronics recycling program.

Fermilab has a comprehensive program for the handling, storage, and disposal of both radioactive wastes and hazardous chemical wastes. The various waste programs are described in the FESHM, Chapter 802. DECam construction is not expected to generate any radioactive wastes. There may be generation of chemical waste, in small amounts, and such waste will be handled according to the relevant sections of the FESHM.

6.2 Safeguards and Securities Plan and Vulnerability Assessment

Safeguards and security will be covered under Fermilab's existing DOE-approved program. The DECam Project will create no new security issues during design or fabrication. DECam has no special nuclear material (enriched uranium or plutonium) and no nuclear material (natural or depleted uranium). Thus extra protective measures are not required. Access to Fermilab is controlled to ensure worker and public safety and property protection. None of the work on the DES or on the DECam Project is classified. The risk of safeguards and security issues is, therefore, small. DECam is not an attractive target for terrorists, theft, or malicious action. Therefore, due to the 24/7 security force on site, Fermilab's safeguards and security program, and the non-attractiveness of DECam as a target, the vulnerability assessment is very low.

No laboratory safeguards and security requirements will need to be changed for installation or operations subsequent to project completion

6.3 Preliminary Plan for Demobilization of Replaced Facilities

The only facility to be replaced is the MOSAIC II instrument which currently occupies the prime focus cage on the Blanco telescope. The responsibility for unmounting and decommissioning the MOSAIC II rests with CTIO [or the MOSAIC team/collaboration??], not with the DECam project.

6.4 Preliminary Plan for Decontamination and Decommissioning

It is the policy of Fermilab to maintain information necessary for future Decontamination and Decommissioning (D&D) of any or all of the facilities at the Laboratory. The eventual D&D of the beamlines, accelerators and other facilities at Fermilab, will be done in accordance with the provisions of FESHM, Chapter 8070. The major facility used during DECam construction is the Silicon Detector Facility (SiDet). The DECam project will comply with any documentation requirements regarding its use of SiDet with regard to eventual D&D for that facility. No hazardous materials are used in the construction of DECam [check on this].

The decommissioning of the DECam upon completion of the Dark Energy Survey is addressed in the Memorandum of Understanding between NOAO and Fermilab, which states:

"Upon completion of the Dark Energy Survey, the DECam will be transferred from CTIO to Fermilab, at Fermilab's expense. Fermilab will return the property contributed by the Collaborating Institutions in accordance with arrangements made with those institutions. AURA will retain title to its contributed equipment. Other arrangements may be made with the interested parties before the completion of the Dark Energy Survey.

"Return of DECam hardware to Fermilab will be performed in accordance with any applicable US import control laws and regulations."

6.5 Preliminary Management Control Documents

6.5.1 Memoranda of Understanding

The DECam project is being carried out by the DES Collaboration. The portion of the work carried out a Fermilab is the responsibility of the Universities Research Association, which operates Fermi National Accelerator Laboratory (Fermilab) under Contract DE-AC02-76-CH- 03000. The UK- Consortium and the DES-Spain Consortium have committed to provide subsystems for DECam as in-kind contributions through MOU's with Fermilab.

6.5.1 Project Execution Plan

The DECam Project Execution Plan (PEP) summarizes the mission need and justification of the DECam project, its objective and scope, the Department of Energy (DOE) management structure, the resource plan, and the environmental, safety, and health (ES&H) requirements. In addition, it establishes the technical, cost, and schedule baselines for the project, as well as the DOE Baseline and Change Control thresholds. The DECam Preliminary PEP was [will be] submitted to DOE for approval on July xx, 2006.

6.5.3 Project Management Plan

The DECam Project Management Plan (PMP), which is a complementary document to the PEP, describes the organization and systems that the contractor will employ to manage the execution of the project and report to DOE. Subsequent changes to the project scope, cost, or schedule exceeding thresholds defined in the PEP will be traceable, and made in accordance with the Change Control procedures described in the PEP.

7. Project Reviews

The DECam Project will undergo a series of reviews to monitor the progress of the cost, schedule, technical aspects and safety of the project.

7.1 Technical Reviews

The Dark Energy Survey project, encompassing the DECam project being described here as well as the other major DES components (the optical corrector system and the data management project) will have at least one full-scale technical review by September of 2006. For all major procurements there will be a final design review before the purchases are initiated in order to ensure that the design and specifications meet the need of the project and that value engineering principles have been applied.

7. 2 ES&H Reviews

All technical reviews cover the ES&H aspects of the project and thus the ES&H reviews may be part of the overall technical review, instead of its own standalone review. Additional ES&H reviews may be scheduled at the Project Manager's discretion. The Project Manager will address any findings of noncompliance with ES&H requirements and inform the Division Head in writing of the resolution of those findings.

7.3 Director's Reviews

The Fermilab Director will appoint a committee to conduct periodic reviews of the DECam Project to monitor its progress. Director's Reviews are held at the Director's discretion, typically on an annual basis.

Appendices

Appendix A: Mission Need Statement – Ground-Based Dark Energy Experiment

Appendix B: Work Breakdown Structure

Appendix C: Glossary

Appendix D: List of Abbreviations Used and Definitions [in addition to Glossary?]